[INDEX]

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TITLE: MULTI-POLLUTANT CONTROL WITH DRY-WET HYBRID ESP TECHNOLOGY

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ABSTRACT
Wet electrostatic precipitation technology is a well-established technology for control of acid mists and sub-micron particulate as a final polishing device within an multi-pollutant air pollution control system. Typically, wet ESPs are employed after a FGD system where the flue gas is saturated. This paper presents the concept of installing a wet ESP field directly after a dry ESP in an unsaturated flue gas condition for control of PM2.5, SO_3 mist, SO_2 and mercury. EPRI will fund and Southern Company will host a wet ESP pilot to test the Hybrid dry-wet ESP approach at Alabama Power's Plant Miller during the fall of 2003-2004.

INTRODUCTION
Of the 1,100 coal-fired power plants in the US, approximately 75% have dry ESPs installed and 25% have Flue Gas Desulfurization (FGD) systems. Many plants switched to lower sulfur sub-bituminous and lignite coals over the past decade to avoid the cost of installing FGD systems to meet EPA mandated SO_2 standards.

The issue that is now confronting those plants with only dry ESPs installed burning sub-bituminous and lignite coal is that these lower sulfur coals typically have higher levels of elemental mercury concentrations, which pass through the dry ESP and out the stack. Based on the EPA's Information Collection Request (ICR) data, elemental mercury emissions are four times higher from sub-bituminous coal than eastern bituminous coal (4.0 lb/Tbtu vs. 1.0 lb./Tbtu).

Secondly, where low NOx burners have been installed and there is a high level of unburned carbon in the fly ash, increased opacity from release of these sub-micron particles has created permit and good neighbor issues. Finally, EPA standards for PM2.5 are due out 2005 along with more stringent State regulations for opacity that will require plants to address capturing PM2.5 and acid aerosols, the primary causes of visible emissions.

EXPERIMENTAL

Proposed Concept-Hybrid Dry-Wet ESP

A proposed solution is to add a wet ESP field after the dry ESP. A hybrid dry/wet ESP offers the ability to collect multiple pollutants within the same footprint of the existing dry ESP, should the last field of the dry be retrofitted with a wet field. While the dry ESP section will remove PM10 with high efficiency (>90%), the wet ESP last field can remove PM2.5, SO3 and toxic metals with high efficiency (>90%), while providing some trim control (20%-50%) of SO2 and other gases in addition to removal of mercury.

Historical Background

The first ESP developed in this country was actually a wet ESP to remove a sulfuric acid mist plume from a copper smelter designed by Dr. Cottrell in 1907. The technology has become a standard piece of process equipment for the sulfuric acid industry for over 50 years to abate SO_3 mist, a sub-micron particle. In the past twenty years, wet ESP technology has been employed in numerous industrial applications for plume reduction associated with PM2.5 and SO_3 mist, as well as for removal of toxic metals.

Dry ESPs

Dry ESPs have been used successfully for many years in industrial and utility applications for coarse and fine particulate removal. Dry ESPs can achieve 99+ percent efficiency for particles 1 micron to 10 micron in size. However, they have several limitations that prevent their use in all applications:

- Dry ESPs are not capable of removing toxic gases and vapors that are in a vapor state at 400°F.
- Due to their low corona power levels because of resisitivity, dry ESPs cannot efficiently collect very small (< 1 micron) fly ash particles.
- Dry ESPs cannot handle moist or sticky particulate that would stick to the collection surface.
- Dry ESPs require a lot of real estate for multiple fields due to re-entrainment of particulate.
- Dry ESPs rely on mechanical collection methods to clean the plates, which require maintenance and periodic shutdowns.

Therefore, dry ESPs are not be the best practicable control device to meet the proposed PM2.5 standard, or as a final mist eliminator for acid gas mist on FGD systems.

Wet ESP Technology

Wet ESPs operate in the same three-step process as dry ESPs—charging, collecting and finally cleaning of the particles from a collection surface. However, in a wet ESP cleaning of the collecting electrode is performed by washing the collection surface with liquid, rather than mechanically rapping the collection plates. Because there is no particulate buildup on the collection surface, there is no re-entrainment of collected particulate and much higher power levels can be achieved, allowing for charging of sub-micron particles and mists with collection in the liquid slurry. Typically, a wet ESP follows a wet scrubber where the flue gas is saturated and is used to collect PM2.5, SO_3 (H_2SO_4) and liquid droplets remaining in the flue gas.

Wet ESPs also provide some scrubbing efficiency for acid gases and based upon limited test data, some mercury removal of all mercury species-particulate, oxidized and elemental. Particulate and oxidized mercury, usually in the form of HgO, HgS or HgCl, are water soluble particles, which accounts for their being able to be removed in either a FGD system or a wet ESP device. In addition, a wet ESP also provides partial oxidation effect on elemental mercury from ozone generation due to high voltage corona discharge.

Benefits

The proposed technology solution offers several benefits to traditional methods for removing PM2.5, SO3 mist and mercury.

- There is no sorbent injection system. Therefore the cost of installing, handling, and injecting a sorbent such as activated carbon is eliminated.

- There is no fabric filter device. The wet ESP replaces the fabric filter and offers several advantages- less pressure drop, no moving parts, less maintenance.

- Less real estate is required. A wet ESP field can be retrofitted to an existing dry ESP, thereby avoiding the problem of trying to find space for new equipment within the confines of a plant.

- There is no contamination of fly ash. Injection of activated carbon in front of the dry ESP contaminates the fly ash and makes it unmarketable, thereby forfeiting an economic benefit to a plant. A dry ESP retrofitted with a last wet field does not contaminate the fly ash collected in the dry ESP hoppers.

- The flue gas remains above the saturation dew point. While the wet ESP would be constructed of a high-grade stainless steel alloy to avoid corrosion issues, remaining in an unsaturated condition allows for use of the existing duct and stack without costly material upgrades.

- Multiple pollutant control is possible. A wet ESP is primarily a particulate control device, similar to a fabric filter, but offers the collateral benefit of being able to abate acid mists (SO3), some acid gas (SO2, HCL) as well as mercury.

- It can remove both oxidized and particulate forms of mercury, along with partial oxidation of elemental mercury, within the wet ESP field.

- It has low pressure drop, less than 1"w.c., therefore low energy usage.

- Once the oxidized/particulate mercury is collected in the wet ESP slurry, it can be treated in a wastewater treatment system to remove the mercury from the water, concentrating it and reducing mercury handling issues and disposition of a hazardous waste.

- Wastewater from the wet ESP can be either sluiced with fly ash from the dry ESP hoppers to an ash pond or a wastewater treatment system incorporated with recycle and bleed to minimize water and further concentrate captured pollutants into a dry cake for disposal.

Cost

Croll-Reynolds wet ESP technology has been quoted on a firm capital cost basis at full scale levels (50MW-900MW) at between $20-$4/kw installed, depending upon size and difficulty of the installation. Operating costs are minimal with less than 3watts/cfm power usage within the wet ESP. Since pressure drop is less than ½" across the device, energy consumption is minimal. Wastewater treatment is an added expense, but typically less than $2/kw annually.

RESULTS AND DISCUSSION

Test Results

The Electric Power Research Institute tested the concept of adding a wet ESP after a dry ESP in an unsaturated condition during 1994-1995 at pilot scale level on coal-fired flue gas, primarily for opacity abatement. Those results indicated that a single wet field can achieve very high collection efficiency, greater than 90 percent. In terms of outlet emissions, the tests indicated that a dry ESP emitting more than 0.1 lb/MMBtu before conversion would emit less than 0.03 lb/MMBtu after conversion to a wet field. This high efficiency results from the high power levels possible when fly ash electrical resistivity is no longer a controlling factor.

Furthermore, the water wash system in the wet field eliminates the need for traditional mechanical rapping and thus virtually eliminates all re-entrainment losses. The EPRI tests also established that a wet ESP can successfully operate with the flue gas temperature well above the moisture dew point. This method of operation means that equipment downstream of the converted ESP will not have to be operated below the due point. Finally, the EPRI tests demonstrated that the conversion to wet operation reduced SO2 and other pollutants including mercury. Measured results from the pilot showed the following removal levels across the wet ESP.

- Particulate matter: 95%
- Sulfur dioxide: 20%
- Hydrogen chloride: 35%
- Hydrogen fluoride: 45%
- Oxidized Mercury: 50%
- Total mercury 30%*

(*It is estimated that some of the oxidized mercury degassed back to elemental mercury in the water solution due to improper pH control/water chemistry.)

In 2000-2001, EPRI funded a full-scale demonstration of this concept at Mirant's Dickerson Station for opacity reduction. While performance testing reported high collection efficiency on PM2.5 and SO_3 with reduced opacity to 10%, mechanical issues associated with the wet ESP design, which could have been corrected if non-technical issues had not limited the length of the project, prevented continued implementation of this approach. No mercury testing was performed at this site. Croll-Reynolds has since designed and installed a horizontal, plate wet ESP at slip-stream pilot scale that overcomes the mechanical issues experienced at Dickerson with over 95% PM2.5 collected.

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Croll-Reynolds other pilot wet ESP is installed at First Energy's Bruce Mansfield Station in Shippingport, Pa. This 2,500 MW plant burns 3% bituminous coal and has a FGD system installed for PM10 and SO_2 control. A 5,000 acfm (2 MW) pilot scale Croll-Reynolds wet ESP was installed for PM2.5 and SO_3 control, the two primary contributors to stack plume. Speciated mercury testing was also performed to measure collateral benefits of installing wet ESP technology. Test results during September of 2001 showed the following:

Table 1. Summary of Pilot Wet ESP Test Results- Bruce Mansfield Plant

					Mercury		
	PM2.5		**SO_3 Mist**		**Particulate**	**Oxidized**	**Elemental**
Average of all Tests							
Test Series	Sep-01	Nov-01	Sep-01	Nov-01	Sept –01	Sept -01	Sept –01
Airflow-acfm	8394	8235	8394	8235	8000	8000	15000
Velocity – ft./sec.	10	10	10	10			
# of fields	1	2	1	2	1	1	1
Power Levels	100%	100%	100%	100%	100%	100%	100%
					ug/dscm	ug/dscm	ug/dscm
Inlet	0.0292	0.0506	11.475	10.01	0.011	0.689	6.245
Outlet	0.0063	0.002	2.7	0.85	0.004	0.158	3.474
Removal %	**79%**	**96%**	**76%**	**92%**	**64%**	**77%**	**44%**

The initial series of tests completed during Sept. of 2001 were performed in a single electrical field at approximately 8,000 cfm. (Note: the pilot wet ESP was designed for 90% removal of PM2.5 and SO_3 at 5,000 cfm.) Removal achieved at this higher air-flow was 79% for PM2.5 and 76% for SO_3. Mercury testing showed 64% for particulate, 77% for oxidized and 44% for elemental. Removal levels for particulate and oxidized mercury were similar to that for PM2.5 and SO_3. Most importantly, 44% removal of elemental mercury was measured at the highest inlet concentration. Total mercury removed was 48% since the greatest fraction of mercury in the flue gas was elemental. (6.245 ug/dscm out of total mercury inlet of 6.945). Oxidized mercury levels were relatively low because most of the mercury was presumably already removed in the upstream FGD system. It is estimated that at higher inlet levels, higher removal efficiencies would be expected.

The pilot wet ESP was modified during October of 2001 into two electrical fields while maintaining the same mechanical dimensions. Testing for PM2.5 and SO3 were repeated and removal efficiency increased to 96% for PM2.5 and 92% for SO_3. No additional mercury testing was performed due to financial and timing limitations. However, it could be expected that total mercury removal would also have improved in this two-field configuration. <u>If particulate and oxidized mercury are removed at similar levels as PM2.5 and SO_3, potentially 90% of particulate/oxidized species of mercury could be removed and 50% of elemental mercury within a wet ESP device.</u>

However, 75% of all coal-fired plants do not have a FGD system installed. Successful demonstration of a wet ESP after a dry ESP with no FGD installed for mercury control clearly represents an opportunity to provide a cost-effective, multi-pollutant control alternative for a majority of existing coal-fired plants.

The wet ESP proposed for this project represents a unique and different application for wet ESP technology, as the flue gas will not be saturated. Flue gas temperature will remain at least 80^{o} F. above saturation point. As demonstrated by EPRI in their wet ESP pilot and at Mirant's Dickerson station, this approach can succeed from a process perspective. The challenges are the mechanical issues of how to introduce the liquid, how to keep it on the entire collection surface and how to avoid liquid spray in the electrical field can be overcome.

New Pilot Demonstration

The Electric Power Research Institute and Croll-Reynolds are under contract to construct a mobile 5,000 cfm slip-stream pilot wet ESP after an existing dry ESP to test for PM2.5, SO2, SO3 and mercury removal at Southern Company's Alabama Power's Plant Miller. Plant Miller burns PRB coal and is installing SCR technology for further NOx abatement during 2003, which will be operational in 2004. The pilot will incorporate CRCAT's patented Plasma Enhanced ESP technology for mercury control. Laboratory testing has demonstrated up to 80% oxidation of elemental mercury in the PEESP device. Oxidized mercury can be collected in the wet ESP field at similar levels as PM2.5.

The pilot wet ESP consists of stainless plates with a patented water feed system that promotes uniform and thorough water coverage while minimizing the potential for plugging, splashing and mist carryover. Custom designed ionizing electrodes are configured to suit the electrical profile required for flue gas concentrations in order to maximize the removal efficiency of particulate and liquid droplets and oxidation of level of elemental mercury in the high voltage corona discharge. The PEESP technology consists of injecting a proprietary reagent through the central discharge electrodes into the flue gas.

CONCLUSION

Wet ESP technology is a proven, well-known technology that can achieve very high removal of mists, particles and aerosols with low pressure drop and minimum maintenance, if properly designed and built. It is being recognized as a technology to be employed as a final polishing device for multiple pollutants to meet future regulations for SOx, PM2.5, mercury and other hazardous air pollutants.